Utilisation of Recron 3s Fibres and Tile Waste for Improving the Performance of Flexible Pavement System

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Abstract–*Flexible pavement construction over weak expansive soil subgrades is characterized by high construction and maintenance costs, which adversely affect the economic viability of road infrastructure projects. The primary reason for this is the poor engineering behaviour of expansive soils, which undergo significant volume changes due to fluctuations in moisture content, resulting in differential settlement, cracking, and premature pavement distress. To address these challenges, considerable research has been directed toward developing cost-effective and sustainable reinforcement techniques that can enhance the properties of weak subgrades and improve the overall performance and durability of flexible pavements. Such stabilization methods also help reduce the frequency of maintenance and rehabilitation. The present study assesses the effectiveness of tile waste and Recron 3S fibre as reinforcing materials for expansive soil stabilization. The incorporation of these materials is intended to improve the strength and durability of the expansive soil while minimizing its undesirable characteristics. Consequently, the stabilized expansive soil can be effectively utilized as a pavement subgrade, leading to improved pavement performance and enhanced economic viability. Laboratory tests, including C.B.R. and plate load tests, were conducted in the laboratory and laboratory plate load results were confirmed in the field by constructing an off-lane test track This study concludes that alternative reinforcement materials, Recron 3s Fibres and Tile waste, can be a viable and sustainable option in pavement performance, especially in expansive soil areas.*

Keywords: Expansive soils, Reinforcement technique, Sub-base, Tile waste, Recron 3s Fibre.

1. INTRODUCTION

A large portion of the land area in India is covered by soft and weak soils, which create challenges for economical pavement construction. Among these weak soils, expansive soils cover about 20% of the total land area of India. The main critical characteristic of expansive soil is its swell–shrink behavior. It swells when it absorbs water and shrinks when it loses moisture. Pavements constructed over expansive soils without proper stabilization may develop cracks, deformation, and other failures due to the volume changes in the soil. Therefore, proper soil stabilization is important to improve the performance and durability of pavements constructed over expansive soil.

On the other hand, increased demand for building material like ceramic tiles has depleted natural resources at an alarming rate [1]. Use of Recron 3S fiber in the stabilization of black cotton soil to enhance its engineering behavior. It was observed that the unconfined compressive strength of the Expansive soil–Fly ash mixture increased with the addition of Recron 3S fibers, with the highest strength obtained at the optimum fiber content of 0.8%. This increase in strength was mainly due to the reinforcing effect of the Recron 3S fibers [2]. The optimum tile waste content was found to be 30%, which resulted in improvements in the shrinkage limit, maximum dry density, unconfined compressive strength (UCS), and California bearing ratio (CBR) of the soil. However, further increases in tile waste content led to a reduction in the engineering properties of the soil. The study indicates that ceramic tile waste can be used as an economical and sustainable material for stabilizing expansive soils [3]. The compaction behavior of soft marine clay stabilized with recycled blended tiles (RBT) of 0.3 mm and 1.18 mm particle sizes was investigated. RBT was added at 10%, 20%, 30%, and 40% by weight of the soil. The results showed that the addition of RBT increased the maximum dry density (MDD) of the marine clay. The study revealed that RBT acted as a strengthening agent by improving the bonding between the soil particles. The larger RBT particles were found to be more effective in improving the compaction characteristics of the treated soil [4]. The effects of sisal and jute fibers on the dry density and California bearing ratio (CBR) of expansive soil were studied by adding 2%, 4%, 6%, and 8% fibers. The results showed that the maximum dry density was obtained at 6% fiber content for both sisal and jute fibers. A significant improvement in CBR was observed with the addition of sisal fiber, jute fiber, and a combination of both fibers to the expansive soil. However, the study did not investigate the behavior of the stabilized soil under cyclic loading or its long-term durability [5]. Ceramic tile waste improves the engineering properties of soil by reducing the liquid limit and plasticity and increasing the maximum dry density, unconfined compressive strength (UCS), and California bearing ratio (CBR). Similarly, recycled tire waste improves soil strength and bearing capacity due to its reinforcing effect, particularly when used with cement or lime. The review indicates that the use of these waste materials for soil stabilization provides both environmental and economic benefits [6]. It was found that the incorporation of 12% of Ceramic Waste Powder lowered the values of the liquid limit, plasticity index, free swell, and optimum moisture content but raised those of maximum dry density, unconfined compressive strength, and soaked CBR. The optimum percentage of Ceramic Waste Powder, which is 12%, helped raise the CBR value from 3% to 19%[7]. Expansive soils exhibit significant swell–shrink behaviour due to seasonal moisture variations, making them unsuitable for pavement subgrades without modification. Previous studies have demonstrated that fly ash and reinforcement techniques can effectively improve the strength and reduce the swelling characteristics of expansive soils. Geosynthetics and alternative waste materials have also shown potential for enhancing pavement load-carrying capacity and deformation resistance. However, most investigations have been limited to laboratory studies, with comparatively fewer field test-track evaluations. Therefore, further research is required to validate sustainable stabilization techniques under field-simulated conditions [8].

The present investigation aimed to improve the strength characteristics of expansive soil and determine the optimum combination of tile waste (TW) and Recron 3S fibers. Tile waste was added at 5%, 10%, 15%, 20%, and 25% by dry weight of the soil, while Recron 3S fibers were incorporated at dosages of 0.5%, 1.0%, 1.5%, and 2.0%. A series of compaction, soaked California bearing ratio (CBR), and load tests were conducted to evaluate the Strength behavior of the treated soil.

2. HIGHLIGHTS

- The effects of tile waste and Recron 3S fibers on the Strength properties of expansive soil were investigated.
- The use of industrial waste materials provides a sustainable and cost-effective approach to reducing road construction costs, particularly in rural areas.

3. MATERIALS

3.1 Black Cotton Soil (ES):

The soil sample used in this investigation was collected from Odalarevu, near Amalapuram, Andhra Pradesh, India, The geotechnical properties of the expansive soil were determined in accordance with the relevant Indian Standard (IS) codes. The properties are summarised in the table.

Table -1: Properties of Black cotton soil

Property	**Value**
Liquid Limit (%)	85
Plastic Limit (%)	36
Plasticity Index (%)	49
Soil Classification	CH (Highly Plastic Compressibility)
Specific Gravity	2.66
Differential Free Swell (%)	140
Maximum Dry Density (g/cc)	1.55
Optimum Moisture Content (%)	29.17
Soaked California Bearing Ratio (%)	1.34

Plate-1: Black cotton soil

The results indicate that the collected soil, as shown in Plate-1, can be classified as highly plastic clay (CH) with a high swelling potential. Therefore, stabilisation is required to improve its Strength properties and make it suitable for engineering applications.

3.2 Tile waste (TW)

In this study, tile waste was collected from local under-construction buildings in Kakinada, Andhra Pradesh, as shown in Plate-2. The collected tile waste was broken into small pieces, as shown in Plate-2. Tile waste was added to the soil at 10%, 15%, 20%, and 25% by dry weight of the soil.

Plate -2: Tile Waste

3.3 Recron 3s Fibre

Recron 3S is a modified polyester fibre commonly used as a reinforcing material in concrete and soil to improve their engineering properties. In this study, Recron 3S fibres manufactured by Reliance Industries Limited were used as shown in Plate 3.. The fibres were added to the soil at contents of 0.5%, 1.0%, 1.5%, and 2.0% by dry weight of the soil.

Plate -3: Recron 3S Fibre

4. EXPERIMENTAL INVESTIGATIONS

In this study, different percentages of tile waste (TW) were mixed with black cotton soil by dry weight to evaluate their effect on the geotechnical properties of the soil and determine the optimum TW content. The soil with the optimum TW content was then reinforced with different percentages of Recron 3S fibers. The soaked California bearing ratio (CBR), and cyclic plate load performance of the treated soil were evaluated. All laboratory tests were conducted in accordance with the relevant Indian Standard (IS) codes. A field test track was also constructed using the optimum percentages of TW and Recron 3S fibers to verify the laboratory results under practical field conditions.

4.1 California Bearing Ratio (CBR)

CBR test has been conducted on treated and untreated expansive soil as per IS: 2720 part XVI-1987, with various proportions of Tile waste and Recron 3S fibre under soaked conditions. The mix proportions considered for expansive soil stabilisation using tile waste and Recron 3S fibre are schematically presented in Plates 4 and 5. Tile waste was incorporated at 10%, 15%, 20%, and 25%, while Recron 3S fibre was added at 0.5%, 1.0%, 1.5%, and 2.0% to the optimum expansive soil–tile waste mixture.

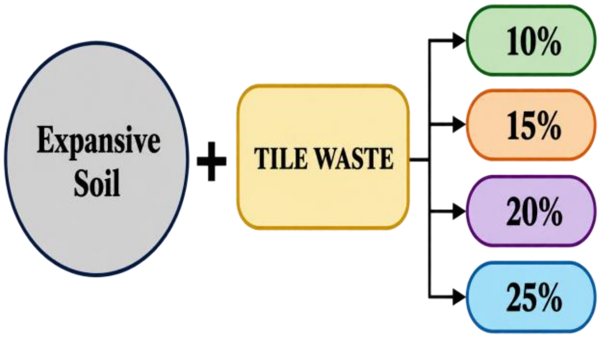


Plate-4: Schematic representation of the proposed expansive soil–tile waste stabilization mixtures.

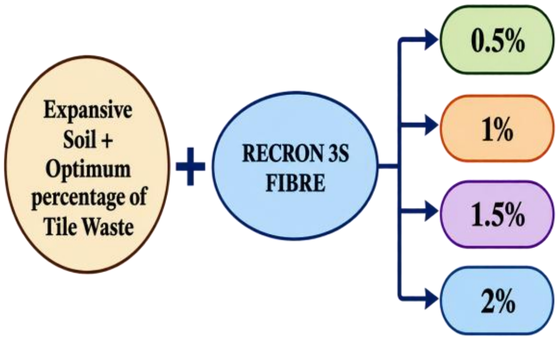


Plate-5 : Schematic representation of the proposed expansive soil–tile waste–Recron 3S fibre stabilization mixtures.

4.2 Laboratory Cyclic Plate Load Test

A laboratory cyclic plate load test was carried out to assess the load-carrying capacity and settlement behaviour of the treated soil under cyclic loading and unloading. A model flexible pavement was prepared in a steel test tank, consisting of a 15 cm thick layer of treated expansive soil as the subgrade, a 5 cm thick gravel layer as the sub-base, and a 5 cm thick WBM-III layer as the base course. A circular steel plate of 10 cm diameter was placed on the pavement surface to apply the load as shown in Plate 6.

The steel tank was positioned on a compression testing machine, and a hydraulic jack with a capacity of 500 kN was used to apply the required load. Two dial gauges with a least count of 0.01 mm were installed to measure the pavement settlement during loading.

The tests were conducted on soil specimens prepared at their respective optimum moisture content (OMC). Loading pressures of 500, 560, 630, 700, 1000, and 1200 kPa were applied in stages. At each pressure level, six loading and unloading cycles were performed. The test was continued until the settlement readings became stable, with negligible differences between successive cycles. The test results were used to evaluate the settlement and load-carrying behavior of the treated soil under cyclic loading.

Plate - 6: Experimental Cyclic Plate Load Set for Finding Load – Settlement

4.3 Field Test track Studies

Controlled laboratory investigations were conducted to evaluate the effects of tile waste (TW) and Recron 3S fibers on the geotechnical properties of expansive soil. The laboratory results were further validated through a field test track study. The test track consisting of subgrade, sub-base, and base course layers was constructed. Cyclic plate load tests were then performed to evaluate the load-carrying capacity and structural performance of the pavement system under practical field conditions.

Two field test tracks as shown in Plate 7, each measuring 4.0 m × 2.0 m, were constructed. The first test track comprised untreated expansive, whereas the second consisted of expansive soil stabilized with 15% tile waste and 1.5% Recron 3S fibre identified through laboratory investigation. Both test tracks were excavated to an average depth of 0.80 m to accommodate the pavement layers. The pavement system consisted of a 0.45 m-thick treated and untreated expansive soil layer serving as the foundation subgrade, overlaid by a 0.15 m-thick gravel cushion layer as the sub-base, and a 0.15 m-thick Water Bound Macadam (WMM) Grade III layer as the base course for both treated and untreated stretches. This multilayer configuration was adopted to simulate the structural characteristics and field conditions of a flexible pavement system and to facilitate the evaluation of the performance of the stabilized expansive soil subgrades under field conditions.

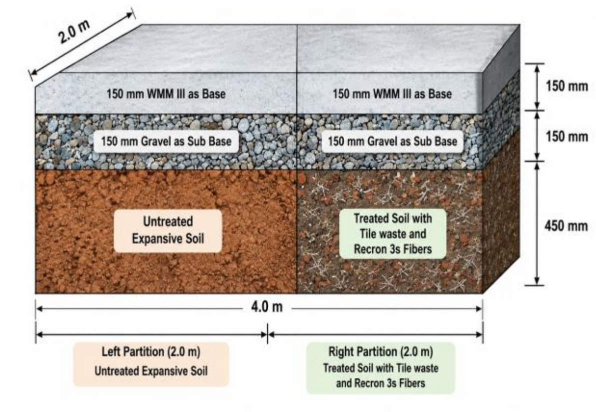


Plate-7: Test Track details constructed in the field

In-situ plate load test, as shown on Plate 8 were conducted on both the stretches for various temperatures ranging from 100 kpa to 1000 kpa.

Plate - 8: Authors conducting field load test on Prepared Test track

5. TEST RESULTS

In the laboratory, a series of tests was carried out on black cotton soil stabilised with varying proportions of Tile waste and Recron 3S fibre to determine the optimum mix ratios and to evaluate their influence on the strength characteristics of the soil. The results obtained from these tests are presented below.

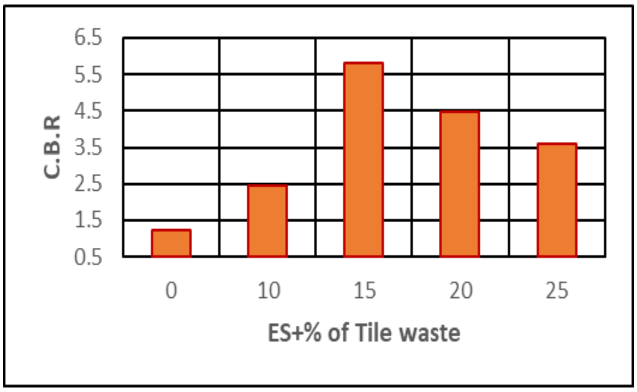
5.1 California Bearing Ratio Test (CBR)

Soaked CBR tests were performed on Expansive soil blended with varying proportions of Tile waste (TW) and Recron 3s fibre, and the results are presented in Graph-1. The soaked CBR values for Expansive soil mixed with 10%, 15%, and 20% and 25% Tile waste were 2.46%, 5.82%, 4.48% and 3.58 respectively, indicating that the maximum CBR value was achieved at 15% TW content.

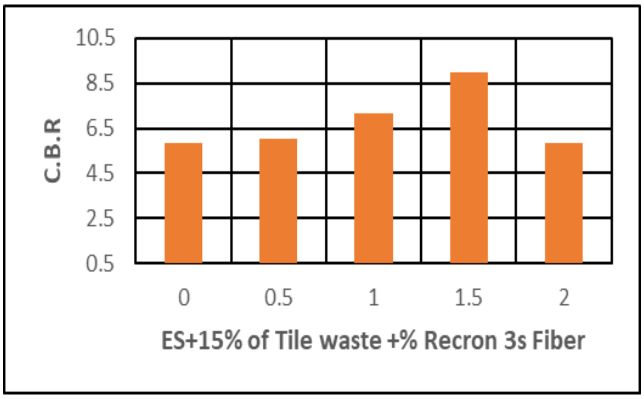
Further, when Recron 3s fibre was incorporated into the

TW-treated expansive soil at proportions of 0.5%, 1.0%, 1.5%, and 2.0% the corresponding soaked CBR values were 6.05%, 7.16%, 8.96%, and 5.83%, as shown in Graph-2. Based on these results, the optimum proportions of Tile waste and Recron 3s fibre were determined to be 15% and 1.0%, respectively. The improvement in compaction characteristics contributed to the increase in CBR values, indicating a significant enhancement in the overall strength of the soil.

Graph-1: Soaked CBR values for Expansive soil treated with different percentages of Tile waste



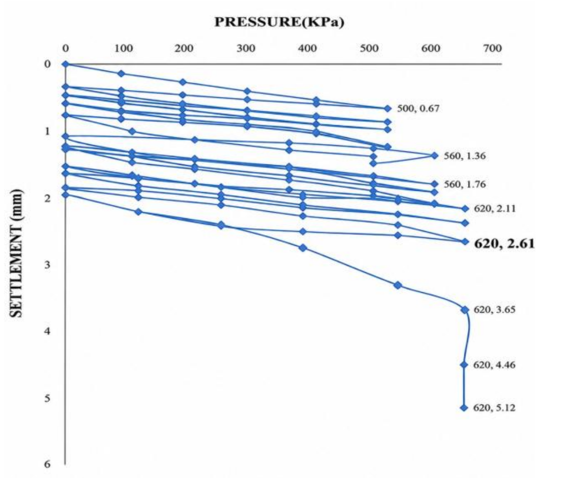
Graph-2: Soaked CBR values for 85% Expansive soil treated with 15% Tile waste and different % of Recron 3s fibre



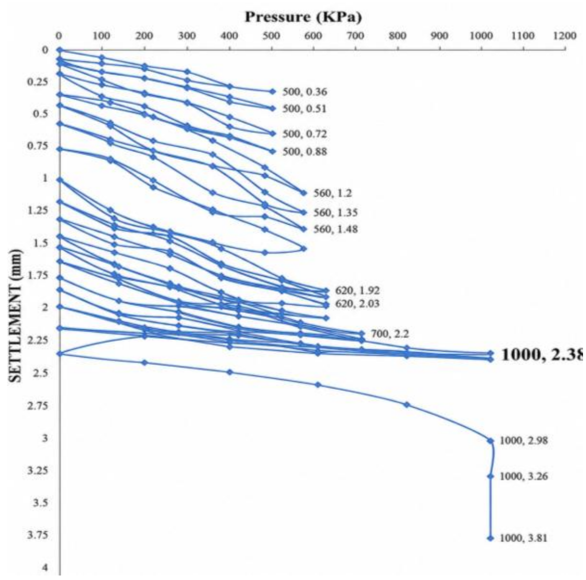
5.2 Laboratory Cyclic Plate Load Test

From the laboratory cyclic plate load test results, the untreated Expansive soil subgrade model of the flexible pavement showed an ultimate bearing pressure of 620 kPa at a deformation of 2.61 mm. In contrast, the subgrade model stabilised with 15% Tile waste and 1.5% Recron 3s fibre exhibited a substantially higher ultimate bearing pressure of 1000 kPa with a reduced deformation of 2.38 mm, as illustrated in Graphs 3 and 4. These results clearly demonstrate a notable improvement in the load-bearing capacity and stiffness of black cotton soil when stabilised with 15% Tile waste and 1.5% Recron 3s fibre compared to the untreated soil.

Graph -3: Laboratory Cyclic plate load test results of untreated Expansive soil at Saturation



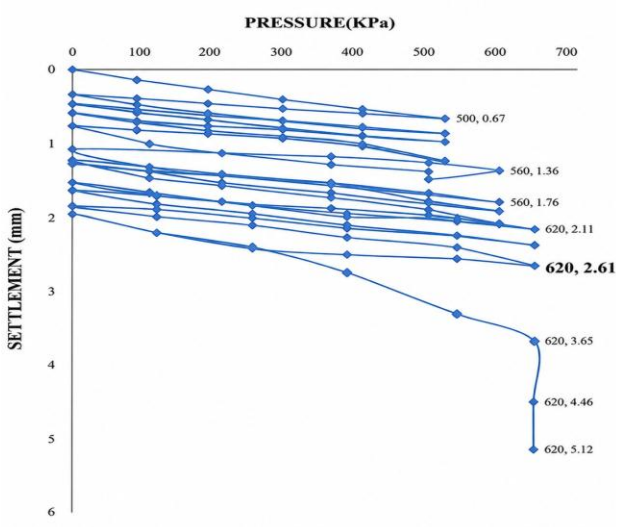
Graph -4: Laboratory cyclic plate load test result of treated Expansive clay with an optimum 15% TW and 1.5% Recron 3s Fibre at Saturation



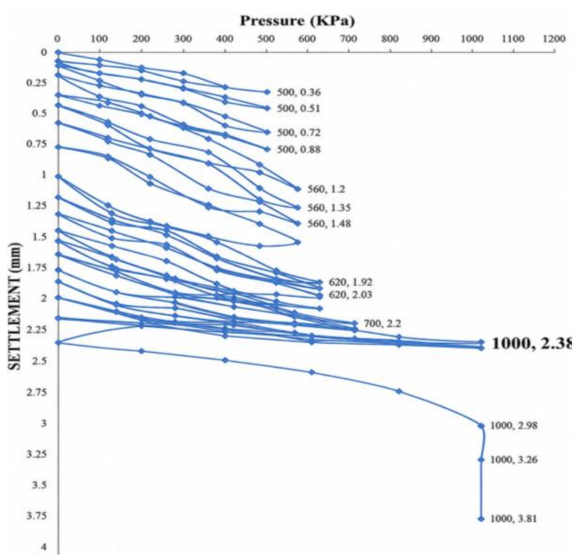
5.3 Field Test track Studies

The field cyclic plate load test results established that the untreated expansive clay subgrade exhibited an ultimate cyclic pressure of 620 kPa at a corresponding settlement of 2.61 mm, as shown in the Graph 5 indicating relatively low resistance to repeated cyclic loading and progressive deformation under increasing applied pressure. This value was considered as the baseline for evaluating the effectiveness of the proposed stabilization treatment. The subsequent field cyclic plate load test demonstrated a marked improvement in the load-bearing and deformation characteristics of the treated subgrade stabilized with 15% tile waste (TW) and 1.5% Recron 3S fibre, wherein the ultimate cyclic pressure increased from 620 kPa to 1000 kPa, while the corresponding settlement decreased from 2.61 mm to 2.38 mm as shown in the Graph-6. The increase in cyclic load-carrying capacity and reduction in settlement clearly indicate the enhanced deformation resistance, load-bearing capacity, and overall cyclic performance of the stabilised expansive clay subgrade.

Graph -5: In-situ cyclic plate load test results of untreated Expansive soil at Saturation



Graph-6: In-situ cyclic plate load test result of treated Expansive clay with an optimum 15% TW and 1.5% Recron 3s Fibre at Saturation



6. CONCLUSIONS

Based on the findings of the laboratory investigations, the following conclusions can be drawn:

1. The soaked California Bearing Ratio (CBR) value increased significantly by 227.64% with 15% TW, and further improved by 118.11% upon the inclusion of 1.5% Recron 3s Fibre, reflecting enhanced load-bearing capacity.
2. The laboratory cyclic plate load test results indicated that the ultimate cyclic pressure of the untreated expansive clay subgrade was 620 kPa, corresponding to a settlement of 2.61 mm.
3. Field cyclic plate load results revealed that the ultimate cyclic pressure of the treated expansive clay increased markedly from 620 kPa (untreated) to 1000 kPa corresponding to Settlement values reduced from 2.61 mm to 2.38 mm with the addition of 1.5% Recron 3s and 15% TW, indicating enhanced deformation resistance of the treated soil.
4. The incorporation of industrial waste materials such as Tile Waste (TW) and Recron 3s fibers provides a sustainable and economical approach for improving subgrade performance, particularly beneficial for rural road construction in developing regions.

REFERENCES

[1] Radhikesh Prasad Nanda, Nijee Priya , Ashutosh Kumar Enhancement of strength of soft soil utilizing construction and demolition wastes reinforced with Recron-3s fibres, Journal of Cleaner production, 2 April 2025.

[2] Tripti Goyal, Er. Rubel Sharma, Experimental study of clayey soil stablised with fly ash and Recron-3s, International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 10, Oct 2018

[3] Sumayya K.P, Mohammed Rafeequedheen.K, Sameer V.T, Firoz, Khais p.t Stabilization of expansive soil treated with tile waste, (SSRG-IJCE) – volume 3 Issue 3–March 2016

[4] Mohammed Ali Mohammed, Al-Bared, Aminaton Marto, Evaluation of the compaction behavior of soft marine clay stabilized with two sizes of recycled crushed tiles, GCEC 2017.

[5] Mr.Sharanakumar, Dr. Vageesha S. Mathad, Amreeta Pawar, Prof. Mallikarjun Honna, Experimental Study on Strength Characteristics of Fiber Reinforced Expansive Soil, International Journal of Engineering Research & Technology (IJERT), Vol. 10 Issue 09, September-2021.

[6] J. Rana Prathap, B. Raghunath Reddy, Utilisation of Recycled Tiles and Tyres in Stabilisation of Soils and Production of Construction Materials, Vol. 11, Issue2, FEB/2020

[7] Rizgar A. Blayi, Bashdar Omer, Frsat A. Ababakr, Bahra S. Yaseen, Afnan M. Jaber, Impact of ceramic waste powder on the geotechnical properties of a clayey soil, Next Materials 11 (2026) 101863, 6 March 2026

[8] A. Sri Avinash, Dr. P. Balakrishna, Performance Evaluation Of Reinforced Flexible Pavements On Different Subgrade, International Journal of Engineering Research & Technology (IJERT), Vol. 10 Issue 12, 12 August 2023.

BIOGRAPHIES

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